IS 3156-1 (1992): Voltage transformers, Part 1: General requirements [ETD 34: Instrument Transformers]

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(Reaffirmed 2002)

भारतीय मानक

वोल्टता ट्रांसफार्मर – विशिष्ट

भाग 1 सामान्य अपेक्षाएं

(दूसरा पुनरीक्षण)

Indian Standard

VOLTAGE TRANSFORMERS - SPECIFICATION

PART 1 GENERAL REQUIREMENTS

(Second Revision)

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(Including Amendment No. 1)

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BUREAU OF INDIAN STANDARDS
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Price Group 8

FOREWORD

This Indian Standard (Part 1) was adopted by the Bureau of Indian Standards, after the draft finalized by the Instrument Transformers Sectional Committee had been approved by the Electrotechnical Division Council.

This standard was first published in 1965 and was subsequently revised in 1978. During the first revision of the standard, high voltage power frequency wet withstand voltage test on outdoor voltage transformers and commissioning test on new voltage transformers were added. Second revision of this standard has been undertaken to bring it in line with the latest developments at international level. In this revision many of the requirements of voltage transformers have been upgraded and a test for short-circuit behaviour of such transformers has been added.

Indian Standards on voltage transformers have been published in four parts :

Part 1 General requirements,

Part 2 Measuring voltage transformers,

Part 3 Protective voltage transformers, and

Part 4 Capacitor voltage transformers.

On the basis of available meterological data concerning the temperature conditions prevailing in several parts of the country during different seasons, a reference ambient temperature of 40°C has been specified in this standard.

In the preparation of this revision assistance has been derived from the following :

IEC Pub 186 (1987) Voltage transformers with Amendment No. 1, December 1988; published by the International Electrotechnical Commission.

BS 3941 : 1975 Voltage transformers with latest amendments, published by the British Standards Institution.

Guidance regarding application of voltage transformers covered by this standard may be obtained from IS 4146 : 1983 and IS 5547 : 1983 (*Under revision*).

For the purpose of deciding whether a particular requirement of this standard is complied with the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

AMENDMENT NO. 1 MAY 1999
TO
IS 3156 (PART 1) : 1992 VOLTAGE TRANSFORMERS — SPECIFICATION
PART 1 GENERAL REQUIREMENTS

(Second Revision)

(*Page* 6, *fourth para of Table* 2) — Substitute the following for the existing:

Table 2 Rated Voltage Factors
(*Clause* 6.6.2)

Method of Connecting the Primary Winding and System Earthing Condition	Rated Voltage Factor	Rating Time
(1)	(2)	(3)
Between line and earth in an isolated neutral system without automatic earth-fault tripping (*see* 3.30) or in a resonant earthed system (*see* 3.31) without automatic earth-fault tripping	1.2 & 1.9	Continuous 8 hours

(ETD 34)

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Indian Standard

VOLTAGE TRANSFORMERS — SPECIFICATION

PART 1 GENERAL REQUIREMENTS

(Second Revision)

1 SCOPE

1.1 This standard (Part 1), covers the general requirements (except as may be modified in the other parts of this standard in respect of certain types) applicable to all voltage transformers for use with electrical measuring instruments and electrical protective devices operating at frequencies from 15 to 100 Hz. It basically applied to transformers with separate windings but where appropriate, it shall apply to auto-transformer type also.

1.2 For three-phase voltage transformers, the requirements of this standard apply only to highest system voltages up to and including 36 kV.

1.3 This standard does not apply to transformers for use in laboratories.

NOTE – Requirements of voltage transformers for use in discharging of capacitor bank should be decided upon by mutual agreement between the manufacturer and purchaser.

2 REFERENCES

2.1 Indian Standards given in Annex A are necessary adjuncts to this standard.

3 TERMINOLOGY

3.0 For the purpose of this standard, the following definitions shall apply.

3.1 Instrument Transformer

A transformer intended to supply measuring instruments, meters, relays and other similar apparatus.

3.2 Voltage Transformer

An instrument transformer in which the secondary voltage, in normal conditions of use, is substantially proportional to the primary voltage and differs in phase from it by an angle which is approximately zero for an appropriate direction of the connections.

3.2.1 *Hermetically Sealed Voltage Transformer*

A liquid immersed voltage transformer which is sealed and does not communicate with atmospheric air.

3.3 Electromagnetic Voltage Transformer

A voltage transformer which transforms the primary voltage to the secondary voltage entirely by electromagnetic phenomena.

3.4 Auxiliary Voltage Transformer

A voltage transformer for matching the rated secondary voltage of the main voltage transformer to the rated voltage of the burden.

3.5 Capacitor Voltage Transformer

A voltage transformer comprising a capacitor divider unit and an electromagnetic unit so designed and interconnected that the secondary voltage of the electromagnetic unit is substantially proportional to and in phase with the primary voltage applied to the capacitor divider unit.

3.6 Measuring Voltage Transformer

A voltage transformer intended to supply indicating instruments, integrating meters and similar apparatus.

3.7 Protective Voltage Transformer

A voltage transformer intended to provide a supply to electrical protective relays and similar apparatus.

3.8 Dual Purpose Voltage Transformer

A voltage transformer having one magnetic core intended to serve the dual purpose of measuring and protection. It may have one or more secondary windings.

3.9 Residual Voltage Transformer

A 3-phase voltage transformer or a group of three single-phase voltage transformers having windings connected in broken delta so as to produce between the appropriate terminals a voltage representative of the residual voltage existing in the 3-phase voltage applied to the primary terminals.

NOTE – A 3-phase residual voltage transformer would have a 5 limbed core.

3.10 Unearthed Voltage Transformer

A voltage transformer which has all parts of its primary winding, including terminals, insulated from earth to a level corresponding to its rated insulation level.

3.11 Earthed Voltage Transformer

A single-phase voltage transformer which is intended to have one end of its primary winding directly earthed or a three phase voltage transformer which is intended to have the star point of its primary winding directly earthed.

3.12 Rated Primary Voltage

The value of the primary voltage which appears in the designation of the transformer and on which its performance is based.

3.13 Rated Primary Voltage

The value of the secondary voltage which appears in the designation of the transformer and on which its performance is based.

3.14 Actual Transformation Ratio

The ratio of the actual primary voltage to the actual secondary voltage.

3.15 Rated Transformation Ratio

The ratio of the rated primary voltage to the rated secondary voltage.

3.16 Voltage Error (Ratio Error)

The error which a transformer introduces into the measurement of a voltage and which arises when the actual transformation ratio is not equal to the rated transformation ratio.

The voltage error, expressed in percent, is given by the formula:

$$\text{Voltage Error} = \frac{k_n . U_s - U_p}{U_p} \times 100 \text{ percent}$$

where

k_n = the rated transformation ratio,

U_s = the actual secondary voltage when U_p is applied under the conditions of measurement, and

U_p = the actual primary voltage.

3.17 Phase Displacement

The difference in phase between the primary voltage and the secondary voltage vectors, the direction of the vectors being so chosen that the angle is zero for a perfect transformer.

NOTES

1 This phase displacement is said to be positive when the secondary voltage vector leads the primary voltage vector and negative when it lags. It is usually expressed in minutes.

2 This definition is strictly correct for sinusoidal voltages only.

3.18 Accuracy Class

A designation assigned to a voltage transformer, the errors of which remain within specified limits under prescribed conditions of use.

3.19 Burden

The admittance of the secondary circuit, expressed in siemens (mhos) and power factor (lagging, leading or unity).

NOTE – The burden is usually expressed as the apparent power in voltamperes absorbed at a specified power factor at the rated secondary voltage.

3.20 Rated Burden

The value of the burden on which the accuracy requirements of this standard are based.

3.21 Rated Output

The value of the apparent power (in volt-amperes at a specified power factor) which the transformer is intended to supply to the secondary circuit at the rated secondary voltage and with rated burden connected to it.

3.22 Thermal Limiting Output

The value of the apparent power referred to rated voltage which can be taken from a secondary winding, at rated primary voltage applied, without exceeding the limits of temperature rise specified in the standard.

NOTES

1 In this condition the limits of error may be exceeded.

2 In case of more than one secondary winding, the thermal limiting output is to be given separately.

3 The simultaneous use of more than one secondary winding is not admitted unless there is an agreement between manufacturer and purchaser.

3.23 Residual Voltage

The vector sum of all three line-to-earth voltages in a three phase system.

3.24 Primary Winding

The winding to which is applied the voltage to be transformed.

3.25 Secondary Winding

The winding which supplies the voltage circuits of measuring instruments, meters, relays or similar apparatus.

3.26 Residual Voltage Winding

The winding of a 3-phase residual voltage transformer or the winding of a single phase transformer intended, in a set of three single-phase transformers, for connection in broken delta for the purpose of:

a) producing a residual voltage under earth-fault conditions, and

b) damping of relaxation oscillations (ferro-resonance).

3.27 Secondary Circuit

The external circuit supplied by the secondary winding of a voltage transformer.

3.27.1 *Nominal System Voltage*

The rms line-to-line voltage by which the system is designated.

NOTE – The rated voltage of apparatus is not necessarily the same as the nominal system voltage.

3.27.2 *Rated Voltage*

The rms value of the voltage used to designate the voltage transformer for a particular highest system voltage.

3.28 Highest System Voltage

The highest rms line-to-line voltage which may be sustained under normal operating conditions at any time and at any point on the system. It excludes temporary voltage variation due to fault conditions and the sudden disconnection of large loads.

3.29 Rated Insulation Level

That combination of voltage values (power frequency and lightning impulse, or where applicable, lightning and switching impulse) which characterized the insulation of a transformer with regard to its capability to withstand dielectric stresses.

3.30 Isolated Neutral System

A system which has no intentional connection to earth except through indicating, measuring or protective devices of very high impedance.

3.31 Resonant Earthed System (System Earthed Through an Arc Suppression Coil)

A system earthed through a reactor, the reactance being of such value that during a single phase-to-earth fault, the power frequency inductive current passed by this reactor substantially neutralizes the power frequency capacitance component of the earth-fault current.

NOTE – With a resonant earthing of a system, the residual current in the fault is limited to such an extent that an arcing fault in the air is self extinguishing.

3.32 Earth-Fault Factor

At a selected location of a three-phase system (generally the point of installation of an equipment) for a given system layout, the ratio of the highest rms phase-to-earth power-frequency voltage on a sound phase during a fault to earth (affecting one or more phases at any point) to the rms phase-to-phase power-frequency voltage which would be obtained at the selected location with the fault removed.

NOTES

1 This factor is a pure numerical ratio (higher than one) and characterizes in general terms the earthing conditions of a system as viewed from the selected location, independently of the actual operating value of the voltage at that location. The 'Earth-Fault Factor' is the product of $\sqrt{3}$ and the factor of earthing, which has been in general use up to now.

2 The earth-fault factors are calculated from the phase-sequence impedance components of the system, as viewed from the selected location, using, for any machines the subtransient reactances.

3 The earth-fault factor does not exceed 1.4, if for all system configurations, the zero-sequence reactance and resistance are less than, respectively, three and one time(s) the positive-sequence reactance.

3.33 Earthed Neutral System

A system in which the neutral is connected to earth, either solidly, or through a resistance or reactance of low enough value to reduce transient oscillations and to give a current sufficient for selective earth fault protection.

3.33.1 *Effectively Earthed Neutral System*

A three-phase system with effectively earthed neutral at a given location in a system characterized by an earth fault factor at this point which does not exceed 1.4 under all conditions of operation.

3.33.2 *Non-effectively Earthed Neutral System*

A 3-phase system with non effectively earthed neutral, at a given location, is characterised by an earth-fault factor at this point that may exceed 1.4.

NOTE – This includes resistance earthed systems and resonant earthed systems where earth faults are not allowed to persist for longer than 8 hours in any 24 hours or a total of 125 hours per annum. For other cases where there is no intentional connection to earth except through indicating, measuring or protective devices of very high impedance or where the duration of earth fault exceeds the period referred above, the manufacturer shall be consulted.

3.34 Electrically Exposed Installation

An installation in which the apparatus is subject to overvoltages of atmospheric origin.

NOTE – Such installations are usually connected to overhead transmission lines, either directly or through a short length of cable.

3.35 Electrically Non-exposed Installation

An installation in which the apparatus is not subject to over-voltages of atmospheric origin.

NOTE – Such installations are usually connected to underground cable networks.

3.36 Rated Voltage Factor

The multiplying factor to be applied to the rated primary voltage to determine the maximum voltage at which a transformer must comply with the relevant thermal requirements for a specified time and with relevant accuracy requirements.

3.37 Rated Frequency

The value of the frequency on which the requirements of this standard are based.

3.38 Type Tests

Tests carried out to prove the general qualities and design of a given type of voltage transformer in accordance with the requirements of this standard. Tests may be carried out on a prototype which may incorporate special arrangements for the measurements required by this standard.

3.39 Routine Test

Test carried out on each voltage transformer to check requirements likely to vary during production.

3.40 Optional Tests

Tests, which may be in the nature of type tests or routine tests, and are carried out only by agreement between manufacturer and purchaser.

4 SERVICE CONDITIONS

4.1 Unless otherwise specified, voltage transformers shall be suitable for the following service conditions. The manufacturer shall be informed if the conditions, including the conditions under which transformers are to be transported, differ from those specified.

4.2 Standard Ambient Conditions

a) Maximum ambient air temperature	Not exceeding 45°C
b) Maximum daily average ambient air temperature	Not exceeding 35°C
c) Maximum yearly average ambient air temperature	Not exceeding 30°C
d) Minimum ambient air temperature	- 5°C

4.2.1 The standard reference ambient temperature shall be 40°C.

4.2.2 Where the ambient temperature conditions given by the user are substantially different from the standard conditions given in 4.2 and if the user has not specified any reference ambient temperature, the reference ambient temperature may be determined in accordance with IS 9676 : 1980.

4.3 Altitude

Up to 1 000 m above mean sea level.

4.4 Atmospheric Conditions

Atmospheres which are not heavily polluted, and atmospheres not conducive to the growth of fungi and condensation of moisture.

4.5 System Earthing

One of the following to be specified:

a) Isolated neutral system (*see* 3.30),

b) Resonant earthed system (*see* 3.31), and

c) Earthed neutral system (*see* 3.33):

i) Effectively earthed neutral system (*see* 3.33.1), and

ii) Non-effectively earthed neutral system (*see* 3.33.2).

5 CONSTRUCTION

5.1 The constructional features of liquid immersed voltage transformers are given in Annex B.

5.2 Earthing

5.2.1 The assembly comprising of the chassis, framework and the fixed parts of the metal casing, where used, of the voltage transformers, shall be provided with two separate earthing terminals. However for indoor type voltage transformers only, one earthing terminal may be provided. These terminals shall be in addition to all other means provided for securing metallic enclosure (armour or other metallic coverings) of current-carrying cables.

5.2.2 The earthing terminals shall be readily accessible and so placed that the earth connection of the voltage transformer is maintained even when the cover or any other movable part is removed.

5.2.3 The earthing terminals shall be of adequate size, be protected against corrosion and shall be metallically clean. Under no circumstances shall a movable metal part of the enclosure be insulated from the part carrying the earthing terminal when the movable part is in place.

5.2.4 The earthing terminal shall be identified by means of the symbol "⏚" marked in a legible and indelible manner on case or frame to be earthed; adjacent to the terminals.

5.2.5 The terminal of high voltage winding intended to be earthed shall be brought out through a bushing, insulated from case or frame to be earthed by a separate connection.

6 RATING

6.1 Rated Frequency

Unless otherwise specified, the rated frequency shall be 50 Hz.

NOTE – Voltage transformers for use on systems of frequency other than 50 Hz shall be considered to comply with this standard if they conform in all other respects with the requirements of this standard at the frequency for which they are intended.

6.2 Rated Primary Voltage

The standard values of rated primary voltage of 3-phase transformers and single-phase transformers for use in a single-phase system or between lines in a 3-phase system, shall be one of the values of nominal system voltage designated in Tables 1A, 1B and 1C (*see* IS 12360 : 1988). The standard values of rated primary voltage of a single-phase transformer connected between one line of a 3-phase system and earth or between a system neutral point and earth shall be $1/\sqrt{3}$ times one of the values of nominal system voltage.

NOTES

1 For voltage transformers in low voltage systems up to 600 V, the user shall specify rated primary voltage.

2 The performance of a voltage transformer as a measuring or protective transformer is based on the rated primary voltage whereas the rated insulation level is based on one of the highest system voltages given in Table 1A, 1B and 1C.

Table 1A Rated Insulation Levels for Highest System Voltages Up to and Including 72.5 kV
(*Clauses* 6.2, 6.7.1, 9.3, 9.6.1 *and* 9.7)

Nominal System Voltage	Highest System Voltage	Power Frequency Withstand Voltage	Lightning Impulse Withstand Voltage	
(1)	(2)	(3)	(4)	
kV (rms)	kV (rms)	kV (rms)	kV (peak)	
			List 1	List 2
Up to 0.60	0.66	3	—	—
3.3	3.6	10	20	40
6.6	7.2	20	40	60
11	12.0	28	60	75
15	17.5	38	75	95
22	24.0	50	95	125
33	36.0	70	145	170
45	52.0	95	250	250
66	72.5	140	325	325

NOTES

1 Underlined values are preferred.

2 The choice between Lists 1 and 2 should be made by considering the degree of exposure to lightening and switching overvoltages, the type of system neutral earthing and the kind of the overvoltage protection. Some guidance is given in IS 2165 (Part 1) : 1977.

Table 1B Rated Insulation Levels for Highest System Voltages of 123 kV and Above Up to and Including 245 kV
(*Clauses* 6.2, 6.7.2, 9.3, 9.6.1 *and* 9.7)

Nominal System Voltage	Highest System Voltage	Power Frequency Withstand Voltage	Lightning Impulse Withstand Voltage
(1)	(2)	(3)	(4)
kV (rms)	kV (rms)	kV (rms)	kV (peak)
110	123	185	450
		230	550
132	145	230	550
		275	650
220	245	360	850
		395	950
		460	1 050

NOTE – Underlined values are preferred.

Table 1C Rated Insulation Level for Highest System Voltage of 420 kV and Above
(*Clauses* 6.2, 6.3.2, 6.7.3, 9.2, 9.6.1 *and* 9.7.1)

Nominal System Voltage	Highest System Voltage	Lightning Impulse Withstand Voltage	Switching Impulse Withstand Voltage
(1)	(2)	(3)	(4)
kV (rms)	kV (rms)	kV (rms)	kV (peak)
400	420	1 175	950
		1 300	1 050
		1 425	1 050
525	525	1 425	1 050
		1 550	1 175
765	765	1 800	1 300
		2 100	1 425
		2 400	1 550

6.3 Rated Secondary Voltage

6.3.1 The rated value for single phase transformers in single-phase systems or connected line-to-line in 3-phase systems, and for 3-phase transformers shall be 110 V.

6.3.2 For single-phase transformers intended to be used line-to-earth in 3-phase systems where the rated primary voltage is a number divided by $\sqrt{3}$, the rated secondary voltage shall be 110 V divided by $\sqrt{3}$, thus retaining the values of the rated transformation ratio.

6.4 Rated Outputs

The rated output at a power factor of 0.8 lagging, expressed in volt-amperes shall be one of the values given below:

10, 15, 25, 30, 50, 75, 100, 150, 200, 300, 400 and 500

NOTES

1 The values underlined are preferred values.

2 The rated output of a 3-phase transformer shall be the rated output per phase.

3 For a given transformer, provided one of the values of rated output is standard and associated with a standard accuracy class, the declaration of other rated outputs, which may be non-standard values but associated with other standard accuracy classes, is not precluded.

6.5 Rated Thermal Limiting Output

Unless otherwise agreed, the thermal limiting output shall be taken as the same as the rated output for which an accuracy rating is given.

6.6 Rated Voltage Factor

6.6.1 The voltage factor is determined by the maximum operating voltage which, in turn, is dependent on the system and the voltage transformer primary winding earthing conditions.

6.6.2 The standard rated voltage factors appropriate to the different earthing conditions are given in Table 2, together with the permissible duration (rated time) of maximum operating voltage.

6.7 Rated Insulation Levels

6.7.1 The rated insulation levels of voltage transformers having highest system voltages up to and including 72.5 kV, defined by the power frequency and the lightning impulse withstand voltage, shall be one of the sets of values given in Table 1A.

6.7.2 The rated insulation levels of voltage transformers having highest system voltages of 123 kV and above up to and including 245 kV defined by the power frequency and lightning impulse withstand voltages shall be one of the values given in Table 1B.

Table 2 Rated Voltage Factors
(*Clause* 6.6.2)

Method of Connecting the Primary Winding and System Earthing Condition	Rated Voltage Factor	Rated Time
(1)	(2)	(3)
Between lines in any network between transformer star point and earth in any network	1.2	Continuous
Between line and earth in any effective earthed neutral system (*see* 3.33.1)	1.2	Continuous
	&	
	1.5	30 Seconds
Between line and earth in a non-effectively earthed neutral system (*see* 3.33.2) with automatic earth fault tripping	1.2	Continuous
	&	
	1.9	30 Seconds
Between line and earth in an isolated neutral system without automatic earth-fault tripping (*see* 3.30) or in a resonant earthed system (*see* 3.31) without automatic earth-fault tripping	1.2	Continuous
	&	
	1.9	

NOTE – Reduced rated times are permissible by agreement between the manufacturer and the user.

6.7.3 The rated insulation levels of voltage transformers having highest system voltage of 420 kV and above defined by the rated switching and lightning impulse withstand voltages shall be one of the sets of value given in Table 1C.

6.7.4 The choice of rated insulation level of a voltage transformer shall be made in accordance with IS 2165 (Part 1) : 1977 and IS 3716 : 1978. If thereby, the rated insulation level is less than any of the sets of values in this standard, the lowest values therein specified shall apply.

7 REQUIREMENTS

7.1 All voltage transformers shall comply with the relevant requirements of this standard. Voltage transformers for dual purpose applications shall comply with the requirements for voltage transformers for both applications.

7.2 Limits of Temperature-Rise

7.2.1 The temperature-rise of a voltage transformer at the specified voltage, at rated frequency and at rated burden, or at the highest rated burden if there are several rated burdens, at any power factor (at the option of the manufacturer) between 0.8 lagging and unity shall not exceed the appropriate value given in Table 3. The temperature-rise of the windings is limited by the lowest class of insulation either of the winding itself or of the surroundings medium in which it is embedded.

The voltage to be applied to the transformer shall be in accordance with 7.2.1.1, 7.2.1.2, and 7.2.1.3 as appropriate.

Table 3 Limits of Temperature-Rise of Windings

(*Clauses* 7.2.1, 7.2.1.2, 7.2.1.3, 7.2.2, 7.2.3 *and* 7.2.6)

Class of Insulation	Maximum Temperature-Rise
(1)	(2)
	K
All Classes immersed in oil	55
All classes immersed in oil and hermetically sealed	60
All classes immersed in bituminous compound	45
Classes not immersed in oil or bituminous compound	
Y	40
A	55
E	70
B	80
F	105
H	130

NOTE – For some materials (such as epoxy resin) the manufacturer should specify the relevant insulation class.

7.2.1.1 All voltage transformers irrespective of voltage factor and time rating shall be tested at 1.2 times the rated primary voltage. The test shall be continued until the temperature of the transformer has reached a steady state.

7.2.1.2 Transformers having a voltage factor of 1.5 for 30 seconds or 1.9 for 30 seconds shall be tested at their respective voltage factor for 30 seconds starting after the application of 1.2 times rated voltage for a time sufficient to reach stable thermal conditions. The temperature-rise shall not exceed by more than 10 K the value specified in Table 3. Alternatively, such transformers may be tested at their voltage factor for 30 seconds starting from the cold condition; and the winding temperature rise shall not exceed 10 K.

NOTE – This test may be omitted if it can be shown by other means that the transformer is satisfactory under these conditions. The test may be omitted provided that the current density in the primary winding(s) under conditions appropriate to the voltage factor specified in 5.6 does not exceed 18.6 A/mm^2 and that the winding conductor is of copper with a conductivity in accordance with IS 4800 (Part 1) : 1968.

7.2.1.3 Transformers having a voltage factor of 1.9 for 8 hours shall be tested at 1.9 times the rated voltage for 8 hours starting after the application of 1.2 times rated voltage for a time sufficient to reach stable thermal conditions. The temperature-rise shall not exceed by more than 10 K the values specified in Table 3.

7.2.2 The values given in Table 3 are based on the standard reference ambient temperature conditions given in 4.2.1. For higher reference ambient temperature in accordance with 4.2.2, the permissible temperature rise in Table 3 shall be reduced by an amount equal to the difference between such reference ambient temperature and 40°C.

7.2.3 If a transformer is specified for service at an altitude in excess of 1 000 m and tested at an altitude below 1 000 m, the limits of temperature-rise given in Table 3 shall be reduced by the following amounts for each 100 m the altitude at the operating site exceeds 1 000 m:

a) Oil-immersed transformers — 0.4 percent, and

b) Dry-type transformers — 0.5 percent.

7.2.4 When the transformer is fitted with conservator tank or has any gas above the oil, or is hermetically sealed, the temperature rise of the oil at the top of the tank or housing shall not exceed 50 K.

7.2.5 When the transformer is not fitted or arranged as in 6.2.4, the temperature-rise of the oil at the top of the tank or housing shall not exceed 45 K.

7.2.6 The temperature-rise measured on the external surface of the core and other metallic parts in contact with, or adjacent to insulation (if accessible) shall not exceed the appropriate value in Table 3.

7.2.7 If a thermal limiting output is specified, the transformer shall be tested at rated primary voltage, with a burden corresponding to the thermal limiting output at unity power factor without loading the residual voltage winding (if any).

7.2.8 If a thermal limiting output is specified for one or more secondary windings, the transformer shall be tested separately with each of these windings connected, one at a time, to a burden corresponding to the relevant thermal limiting output at a unity power factor.

7.3 Short Circuit Withstand Capability

7.3.1 The voltage transformer shall be designed and constructed to withstand without damage, when energized at rated voltage, the mechanical and thermal effects of an external short circuit on secondary terminals for the duration of one second.

7.4 Dielectric Tests

7.4.1 The voltage transformer shall withstand the specified dielectric tests corresponding to the rated insulation level specified.

8 MARKING

8.1 Rating Plate

All voltage transformers shall carry at least the following markings:

a) The manufacturer's name and country of origin;

b) Year of manufacture;

c) A serial number and a type designation;

d) The rated primary and secondary voltage (for example, 66/0.11 kV);

e) Rated frequency;

f) Rated output and the corresponding accuracy class (for example, 50 VA, class 1.0 or 50VA/1);

NOTE – When more than one separate secondary windings are provided, the marking should indicate the output range of each secondary winding in VA, the corresponding accuracy class and the rated voltage of each winding.

g) Highest system voltage (for example, 72.5 kV);

h) Rated insulation level (for example, 140/325 kV);

j) Rated voltage factor and corresponding rated time (for example, 1.9/30s);

k) Number of phases and method of connection (if 3-phase);

m) Earthed or Unearthed; and

n) Reference to this standard.

NOTE – The items (g) and (h) may be combined into one marking (for example, 72.5/140/325 kV).

8.1.1 All information shall be marked in an indelible manner on the voltage transformer itself or on a rating plate securely attached to the transformer.

8.1.2 The following shall be marked by agreement between the purchaser and the manufacturer:

a) Class of insulation

b) The use of secondary winding(s) and the corresponding terminals.

NOTE – If several classes of insulating material are used, the one which limits the temperature-rise of the windings shall be indicated.

8.2 Terminal Markings

The terminal markings shall be in accordance with Annex C.

8.3 The voltage transformers may also be marked with the Standard Mark.

9 TESTS

9.1 Classification of Tests

9.1.1 *Type Tests*

The following shall constitute the type tests:

a) Temperature rise test (*see* 9.5),

b) Lightning impulse test for voltage transformers for service in electrically exposed installation (*see* 9.6),

c) Switching impulse voltage tests for voltage transformers of 420 kV and above (*see* 9.10),

d) High voltage power frequency wet withstand voltage tests on outdoor voltage transformers up to and including 245 kV (*see* 9.7),

NOTE – If the porcelain weather casing/bushing has been subjected to this test separately, the requirements of this test shall be deemed to have been complied with.

e) Determination of errors or other characteristics according to the requirements of the appropriate designation or accuracy class (*see* individual parts of this standard),

NOTES

1 The dielectric type tests in (b), (c) and (d) shall all be carried out on the same transformer unless otherwise agreed.

2 After the transformers have been subjected to the dielectric type tests in (b), (c), and (d), they shall be subjected to all the routine tests.

3 Type tests may be omitted when the manufacturer holds a certificate of type tests made on similar transformer which is acceptable to the purchaser.

9.1.2 *Routine Tests*

The following shall constitute the routine tests:

a) Verification of terminal marking and polarity (*see* 9.2),

b) Power frequency dry withstand tests on primary windings (*see* 9.3),

c) Power frequency dry withstand tests on secondary windings (*see* 9.4),

d) Partial discharge measurement in accordance with IS 11322 : 1985.

NOTE – This test is applicable only for voltage transformers with solid insulation for highest system voltages 7.2 kV and above and voltage transformers with liquid immersed insulation for highest system voltages of 72.5 kV and above. This test is not applicable to capacitor voltage transformers.

e) Determination of errors or other characteristics according to the requirements of the appropriate designation or accuracy class (*see* individual parts of this standard).

NOTES

1 The determination of errors or other characteristics in e) shall be carried out after the tests b and c. The order or possible combination of the other tests is not standardised.

2 Repeated power frequency tests on the primary windings shall be performed at 80 percent of the specified test voltage, except when method of 9.3.3 is used.

9.1.3 *Optional Tests*

The following tests, where applicable, shall be carried out by mutual agreement between the purchaser and the manufacturer:

a) Chopped lighting impulse test as a type test (*see* **9.8**),

b) Short circuit withstand capability test as a type test (*see* **9.9**),

c) Commissioning test on non-earthed voltage transformers of up to and including 36 kV (*see* **9.11**).

9.2 Verification of Terminal Markings and Polarity

Terminal markings and polarity shall be verified to ensure that they are correct.

9.3 High Voltage Power-Frequency Tests on Primary Windings

The test shall be conducted in accordance with IS 2071 (Part 1) : 1974 and IS 2071 (Part 2) : 1974. The test voltages shall be the appropriate power-frequency test voltage specified in Tables 1A, 1B and 4A according to the highest system voltage and the specified rated insulation level.

9.3.1 *Unearthed Voltage Transformers*

Unearthed voltage transformers shall withstand the following tests.

9.3.1.1 *Separate source withstand test*

The test voltage shall be applied for one minute between all the terminals of the primary winding, connected together, and earth. The frame, case (if any), core (if intended to be earthed) and all terminals of the secondary windings shall be connected together and earthed. There shall be no disruptive discharge.

9.3.1.2 *Induced overvoltage withstand test*

At the manufacturer's discretion, the test shall be made by exciting the secondary winding with a voltage of sufficient magnitude to induce the specified test voltage in the primary winding, or by exciting the primary winding directly at the specified test voltage. The test voltage shall be measured at the high voltage side in each case. The frame, case (if any), core (if intended to be earthed) and one terminal of each secondary winding and one terminal of the primary winding shall be connected together and earthed. The frequency of the exciting voltage may be increased above the rated frequency to prevent excessive exciting current and, if the frequency exceeds twice the rated frequency, the duration of the test may be reduced as below :

$$\text{Duration of test frequency} = \frac{\text{Twice the rated frquency}}{\text{Test frequency}} \times 60 \text{ seconds}$$

with a minimum of 15 seconds.

For a 3-phase voltage transformer, the induced voltage test shall normally be made by exciting the secondary winding with a balanced 3-phase voltage at such a value as to induce the specified test voltage between the line terminals of the primary windings. Alternatively, at the discretion of the manufacturer, the induced voltage test on a 3-phase voltage transformer may be made by a succession of single-phase tests. In this case any winding may be earthed at any point at the discretion of the manufacturer; but the test shall be repeated with alternative connections as may be necessary to produce in turn, the required test voltage between line terminals.

NOTES – In no case shall the test voltage for the induced voltage test exceed five times the rated primary voltage.

9.3.2 *Earthed Transformers*

Earthed transformers shall be subjected to the following tests.

9.3.2.1 *Separate source withstand test*

A test voltage of 3 kV rms shall be applied for one minute between the terminal of the primary winding intended to be earthed and earth. The frame, case (if any), core (if intended to be earthed) and all the terminals of the secondary winding shall be connected together and earthed.

9.3.2.2 *Induced overvoltage withstand test*

The test shall be performed in accordance with **9.3.1.2**. The terminal of the primary winding intended to be earthed in service shall be earthed.

NOTE – In case the induced test voltage is limited to 5 times the rated primary voltage, the actual test voltage shall be marked on the rating plate.

9.3.3 If agreed to between purchaser and manufacturer, the induced voltage test on the primary winding of a voltage transformer for highest system voltage of 420 kV and above may be performed by the following alternative method.

9.3.3.1 The transformer shall be subjected to the appropriate specified power-frequency prestress voltage given in Table 4B for 10 seconds. Without inter-

ruption, the voltage shall then be reduced to the corresponding partial discharge test voltage given in Table 4B and this voltage shall be maintained for five minutes. The maximum permissible partial discharge magnitude measured during the last minute at the specified partial discharge test voltage shall be 10 pC. If this method is adopted, it shall not be necessary to carry out the partial discharge test separately.

NOTE – The method in 9.3.1.1 may be preceded by a lightning impulse test in order to complete the dielectric routine tests of the primary winding.

Table 4A Power-Frequency withstand Voltages for Transformer Windings with Highest System Voltage of 420 kV and Above
(*Clause* 9.3.2.2)

Rated Lightning-Impulse Withstand Voltage	Power-Frequency Short-Duration Withstand Voltage
kV (peak)	kV (rms)
1 175	510
1 300	570
1 425	630
1 550	680
1 800	790
2 100	880
2 400	975

Table 4B Power-Frequency Test Voltages for Transformer Windings having Highest System Voltage of 420 kV and Above
(*Clause* 9.3.3)

Highest System Voltage	Power-Frequency Prestress Voltage	Partial Discharge Voltage
kV (rms)	kV (rms)	kV (rms)
420	510	315
525	630	395
765	790/880*	575

*To be determined by the rated lightning impulse withstand voltage.

9.4 High Voltage Power-Frequency Dry Test on Secondary Windings

The test shall be conducted in accordance with IS 2071 (Part 1) : 1974. The test voltage of 3 kV (rms) shall be applied for one minute between all the terminals of the secondary winding (connected together) and earth. The frame, case (if any), core (if intended to be earthed) and all terminals of the primary windings shall have been connected together and earthed. There shall be no disruptive discharge.

9.4.1 When there are more than one secondary windings or sections, each winding or section shall withstand, without disruptive discharge, a test voltage of 3 kV rms applied between that winding and all other windings or sections connected together and earthed.

9.5 Temperature-Rise Test

The voltage transformer shall be tested for compliance with 7.2. It shall be mounted in the manner representative of the mounting in service. It shall be deemed to have attained a steady state temperature when the rate of temperature rise does not exceed $1^{o}K$ per hour. The ambient temperature shall not exceed $40^{o}C$.

The temperature-rise of the windings shall be measured by the increase in resistance method. The temperature-rise of parts other than windings shall be measured by thermometers or thermocouples. For methods of temperature measurements, *see* Annex D.

9.6 Lightning Impulse Voltage Test for Voltage Transformers for Service in Electrically Exposed Installations

9.6.1 Voltage transformers for service in electrically exposed installations shall withstand the appropriate full wave lightning impulse voltage specified in Table 1A, 1B and 1C according to the highest system voltage and the specified insulation level.

9.6.2 The test shall be conducted in accordance with IS 2071 (Part 1) : 1974 and IS 2071 (Part 2) : 1974. The test voltage shall be applied between one line terminal of the primary (high voltage) winding and earth, the appropriate terminals of the windings earthed in accordance with Table 5. The frame, case (if any), core (if intended to be earthed), and all the terminals of the secondary windings shall be connected together and earthed. The test voltage shall have the appropriate values specified in Tables 1A, 1B or 1C according to the highest system voltage and the rated insulation level. The reference impulse voltage shall be between 50 percent and 75 percent of the rated impulse withstand voltage. The peak value and the waveshape of the impulse voltages shall be recorded.

Table 5 High Voltage Terminals to be Earthed during Lightning Impulse Voltage Tests
(*Clause* 9.6.2)

Description of High Voltage Winding (1)	High Voltage Terminal Earthed During Tests (2)
Single-phase earthed	Earth terminal
Single-phase unearthed	Other line terminal
One phase of a 3-phase earthed transformer	Other line terminal and the starpoint earth terminal
One phase of a 3-phase unearthed transformer	Other line terminals

9.6.2.1 At the option of the manufacturer, the earth connection may be made through a suitable current recording device. The secondary (low voltage) terminals may be connected together and earthed or may

be connected to suitable device for recording the voltage wave appearing in the secondary (low voltage) winding(s) during the test.

9.6.2.2 *For indoor voltage transformers up to and including 36 kV,* five consecutive full wave impulses of each polarity with correction for atmospheric conditions shall be applied.

For voltage transformers up to and including 245 kV, fifteen consecutive full wave impulses of each polarity without correction for atmospheric conditions shall be applied. If other tests to check the external insulation (for example, separate lightning impulse test on the weather casing/bushing of oil immersed voltage transformers) have been carried out, the number of lightning impulses should be reduced to three of each polarity without correction for atmospheric conditions.

9.6.2.3 For unearthed single phase transformer, approximately half the number of impulses specified in **9.6.2.2** shall be applied to each line terminal in turn, with the other line terminal connected to earth.

9.6.2.4 For a 3-phase transformer, it is sufficient to test any one of the 3-phases.

9.6.2.5 The voltage transformer shall have passed the test if:

a) No disruptive discharges occur in the non-self-restoring insulation,

b) No flashovers occur along the non-self-restoring external insulation,

c) No more that two flashovers occur across the self-restoring external insulation (only where 15 impulses of each polarity are applied), and

d) No other evidence of failure is detected (i.e. variations in the wave-shape of the recorded quantities).

9.6.3 *For voltage transformers of 420 kV,* three consecutive impulses of each polarity without correction for atmospheric conditions shall be applied.

9.6.3.1 The voltage transformer shall have passed the test if conditions of **9.6.2.5** have been satisfied.

9.7 High Voltage Power-Frequency Wet Withstand Voltage Tests on Outdoor Voltage Transformers

The external insulation of outdoor voltage transformers shall be subjected for one minute to a power-frequency voltage having a peak value equal to $\sqrt{2}$ time the value specified in Tables 2A, 2B appropriate to the highest system voltage and the rated insulation level. The test shall be conducted in accordance with IS 2071 (Part 1) : 1974 and IS 2071 (Part 2) : 1974. This test is applicable only for outdoor voltage transformers up to and including 245 kV highest system voltage.

9.8 Chopped Lightning Impulse Test on Primary Winding

9.8.1 The chopped lightning impulse test shall be carried out with the negative polarity only and shall be combined with the negative polarity full wave have lightning impulse test in the following manner:

a) For highest system voltages up to and including 245 kV where it is considered necessary to test for external insulation:

- one 100 percent full impulse
- two 100 percent chopped impulses
- fourteen 100 percent full impulses

b) For highest system voltages up to 245 kV where external insulation need not be checked by 15 impulses and for highest system voltage of 420 kV and above:

- one 100 percent full impulse
- two 100 percent chopped impulses
- two 100 percent full impulses

9.8.2 The standard lightning impulse shall be chopped after 2 to 5 micro seconds and the chopping circuits shall be so arranged that the amount of overswing to the positive polarity is limited to 30 percent of the chopped impulse.

9.8.3 Significant changes in wave shape of full wave application before and after the application of the chopped impulses are indicative of internal fault.

9.8.4 Flashovers during chopped impulses along self-restoring external insulation should be disregarded during this test.

9.9 Short Circuit Withstand Capability Test

9.9.1 The transformer shall initially be at a temperature between 17°C and 40°C. The voltage transformer shall be energised from the primary side and the short-circuit applied between the secondary terminals. One short-circuit shall be applied for the duration of one second. During the short-circuit, the rms value of the applied voltage at the transformer terminals shall be not less than the rated voltage.

NOTES

1 For inductive type transformers, at the option of the manufacturer, the test may be carried out by energizing the secondary winding and applying the short-circuit between the primary terminals.

2 This requirements applies also where fuses are an integral part of the transformer.

3 In the case of transformers provided with more than one secondary winding or section, or with tappings, the test connection shall be agreed between manufacturer and purchaser.

9.9.2 The transformer shall be deemed to have passed this test, if after cooling to ambient temperature, it satisfies the following requirements:

a) it is not visibly damaged;

b) its errors at rated burden do not differ from those recorded before the tests by more than half the limits of its accuracy class;

c) it withstands the dielectric tests specified in **9.3** and **9.4** but with the test voltage reduced to 90 percent of those given;

d) subject to the Note below, on examination, the insulation next to the surface of both the primary and the secondary windings does not show significant deterioration (for example, carbonization).

NOTE – The examination (d) is not required if the current density in the winding does not exceed 160 A/mm² where the winding is of copper of conductivity not less than 97 percent of the value given in IS 613 : 1964. The current density is to be based on the measured symmetrical rms short-circuit current in the secondary winding (divided by the rated transformation ratio in the case of primary).

9.10 Switching Impulse Test on Voltage Transformers of 420 kV and above

9.10.1 The test shall be carried out in accordance with IS 2071 (Part 2) : 1974. The test voltage shall have the appropriate value in Table 1C according to the specified rated insulation level.

9.10.2 The switching impulse test voltage shall be applied between the line terminal of the primary winding and earth. The earth terminal of the primary winding, one terminal of the secondary winding(s) and the frame, case (if any), and core (if intended to be earthed) shall be connected to earth.

9.10.3 At the option of the manufacturer, the earth connection may be made through a suitable current recording device. The non-earthed secondary terminals may be either left open or connected to high impedance device for recording the voltage wave appearing across the secondary winding(s) during the test.

9.10.4 Fifteen consecutive impulses of both positive and negative polarity, corrected for atmospheric conditions, shall be applied. Outdoor type transformers shall be subjected only to wet tests. Dry tests are not required.

NOTE – To counteract the effect of core saturation, it is permissible, between consecutive impulses to modify the magnetic status of the core by a suitable procedure.

9.10.5 The transformer shall have passed the test if the conditions given in **9.6.2.5** have been satisfied.

9.11 Commissioning Tests on New Transformers

9.11.1 *Power-frequency test on primary windings*

By agreement between the manufacturer and the purchaser, separate source power frequency tests on the primary winding insulation of a non-earthed voltage transformer may be made after erection on site provided that the transformer is in a satisfactory condition for testing and has not been in service. The transformers shall be temporarily disconnected from any other apparatus to which it may be connected. The one minute test voltage shall be 80% of the specified power frequency test voltage.

9.11.1.1 If for any special reasons the duration of the test exceeds one minute, the relationship between duration of the test and the percentage of the one-minute test voltage as given in **9.11.1** shall be as given in Table 6.

Table 6 Applied Power-Frequency High Voltage Tests for Duration Exceeding one Minute (After Erection on Site)

Duration of Test	Percentage of One-Minute Test Voltage
(1)	(2)
minutes	
2	83.5
3	75.00
4	70.0
5	66.6
10	60.0
15	57.7

10 INFORMATION TO BE GIVEN WITH ENQUIRY AND ORDER

10.1 The particulars given in Annex E shall be furnished by the purchaser with each enquiry and order.

ANNEX A
(*Clause* 2.1)

LIST OF REFERRED INDIAN STANDARDS

IS No.	*Title*	*IS No.*	*Title*
335 : 1983	New insulating oils	4146 : 1983	Application guide for voltage transformers
613 : 1984	Copper rods and bars for electrical purposes	4800 (Part 1) : 1968	Enamelled round winding wires : Part 1 Conductors data
2053 : 1974	Thermocouple pyrometers	5547 : 1983	Application guide for capacitor voltage transformers
2071 (Part 1) : 1974	Methods of high voltage testing: Part 1 General definitions and test requirements	5621 : 1980	Hollow insulators for use in electrical equipment
2071 (Part 2) : 1974	Methods of high voltage testing : Part 2 Test procedures	9676 : 1980	Reference ambient temperature for electrical equipment
2099 : 1986	Bushings for alternating voltages above 1 000 V	10601 : 1983	Dimensions of terminals for high voltage switchgear and controlgear
2147 : 1962	Degree of protection provided by enclosures for low voltage switchgear and controlgear	11322 : 1985	Method for partial discharge measurement in instrument transformers
2165 (Part 1) : 1977	Insulation coordination : Part 1 Phase to earth insulation coordination	12360 : 1988	Voltage bands for electrical installations including preferred voltages and frequency
3716 : 1978	Application guide for insulation coordination		

ANNEX B

(Clause 5.1)

CONSTRUCTIONAL FEATURES OF LIQUID IMMERSED VOLTAGE TRANSFORMERS

B-1 PORCELAIN INSULATORS

B-1.1 The hollow porcelain insulator or housing where provided, shall conform to IS 5621 : 1980.

B-1.2 Where demountable bushings are provided, these shall conform to IS 2099 : 1986.

B-1.3 For outdoor voltage transformers for use in polluted atmospheres, the minimum creepage distance measured on the insulation surface and the maximum creepage factor shall be as given below:

Pollution	*Minimum Nominal Specific Creepage Distance Between Phase and Earth (mm/kV of Highest System Voltage)*	*Maximum Creepage Factor*
Light	16	3.5
Normal	20	3.5
Heavy	25	4.0
Very Heavy	31	4.0

NOTES

1 Unless otherwise agreed between manufacturer and purchaser the pollution level shall be deemed to be normal.

2 The creepage factor equals l/S where l is the total creepage distance of the insulator, and S is the arcing distance, which is the shortest distance in air, outside the insulator, not considering arcing horns, between the metallic parts to which the voltage is normally applied.

3 If an insulator has a profile with a creepage factor higher than the limits indicated, the insulator profile may be used if experience in operation, or laboratory test reproducing operation conditions, permits the assumption of good performance. An insulator or bushing, the dimensions of which have been standardised by any Indian Standard shall also be considered to meet this criteria.

4 Protected creepage distance shall not be specified as a parameter characterizing a shed profile.

B-2 OIL

B-2.1 Unless otherwise agreed, the oil used in liquid immersed voltage transformers shall conform to IS 335 : 1983.

B-2.2 The voltage transformer shall be so constructed as to ensure that the oil does not flow out or leak out even when the voltage transformer is used continuously at the maximum allowable temperature.

B-3 PRIMARY TERMINALS

B-3.1 It is suggested (without being mandatory) that the primary terminals of voltage transformers to which the high voltage line connections are to be made shall have the dimensions given in IS 10601 : 1983.

B-4 SECONDARY TERMINALS

B-4.1 The secondary terminals of outdoor voltage transformers shall be brought out in a suitable compartment which shall have a removable cover. The terminal box, with the cover closed and tightened and the cable/conduit in position when supplied shall have a degree of protection conforming to IP 54 of IS 2147 : 1962, unless otherwise agreed.

B-5 Unless otherwise agreed, the external surfaces of the steel tanks of casing of voltage transformers shall be painted with one coat of primer and two coats of synthetic enamel paint. The internal surfaces of the steel tanks or casing shall be painted with two coats of a suitable oil-insoluble paint.

ANNEX C
(*Clause* 8.2)

TERMINAL MARKINGS FOR VOLTAGE TRANSFORMERS

C-0 GENERAL

C-0.1 These markings are applicable to single-phase voltage transformers and sets of single-phase voltage transformers assembled as one unit and connected as a 3-phase voltage transformer, or to a 3-phase voltage transformer having a common core for the three phases.

C-1 TERMINAL MARKINGS

C-1.1 Marking shall be in accordance with Fig. 1 to 10 as appropriate. Capital *A*, *B*, *C* and *N* denote the primary winding terminals and the lowercase letters *a*, *b*, *c* and *n* the corresponding secondary winding terminals.

C-1.2 The letters *A*, *B*, *C* denote fully insulated terminals and the letter *N* denotes a terminal intended to be earthed, and the insulation of which is less than that of the other terminals.

C-1.3 Letters *da* and *dn* denote the terminals of windings intended to supply a residual voltage.

C-2 RELATIVE POLARITY

C-2.1 Terminals having corresponding capital and lowercase markings shall have the same polarity at the same instant.

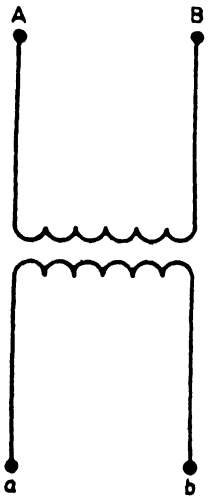

FIG. 1 SINGLE PHASE TRANSFORMER WITH FULLY INSULATED TERMINALS AND A SINGLE SECONDARY

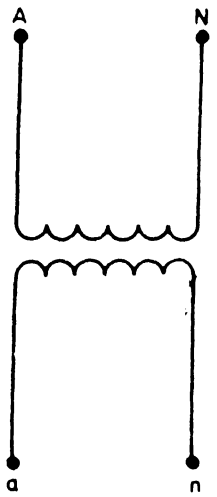

FIG. 2 SINGLE PHASE TRANSFORMER WITH NEUTRAL PRIMARY TERMINAL AND A SINGLE SECONDARY

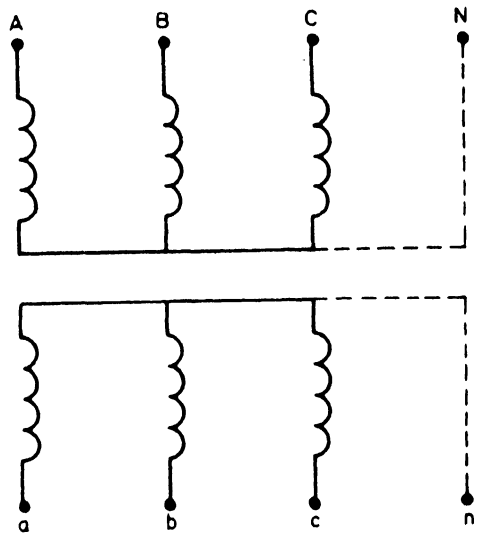

FIG. 3 THREE-PHASE ASSEMBLY WITH A SINGLE SECONDARY

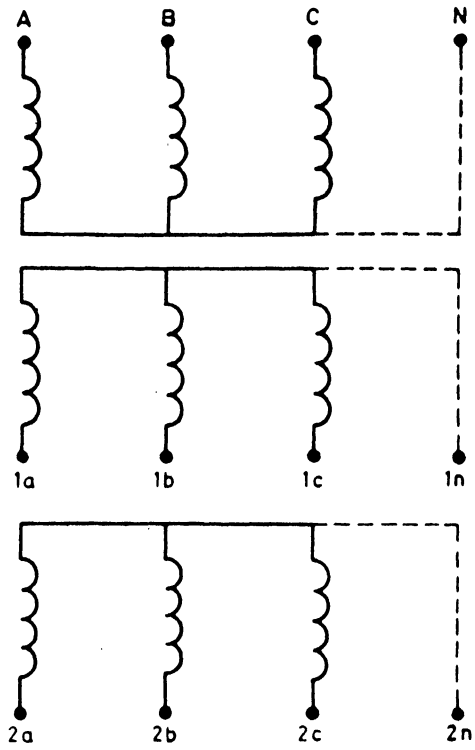

FIG. 5 THREE-PHASE ASSEMBLY WITH TWO SECONDARIES

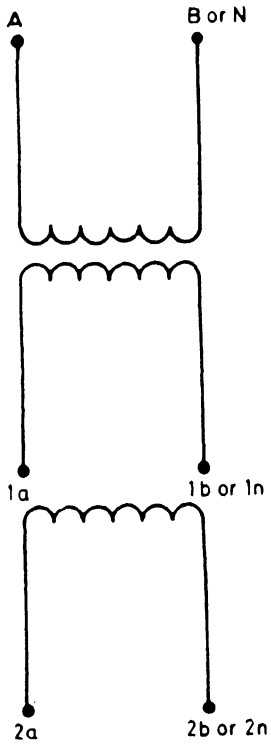

FIG. 4 SINGLE-PHASE TRANSFORMER WITH TWO SECONDARIES

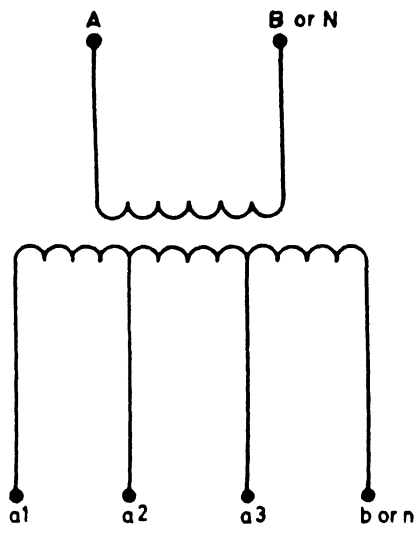

FIG. 6 SINGLE-PHASE TRANSFORMER WITH ONE MULTI-TAP SECONDARY

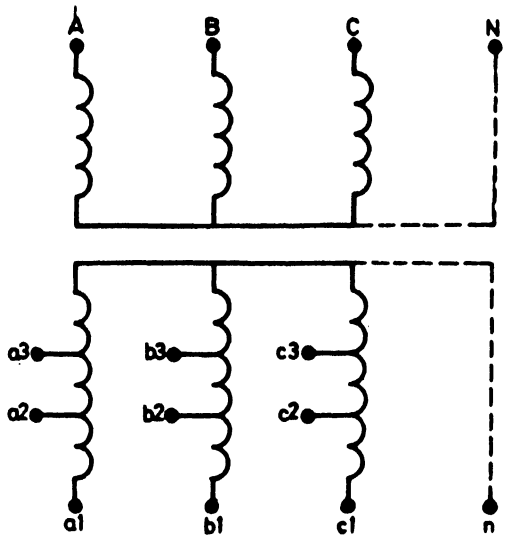

FIG. 7 THREE-PHASE ASSEMBLY WITH ONE MULTI-TAP SECONDARY

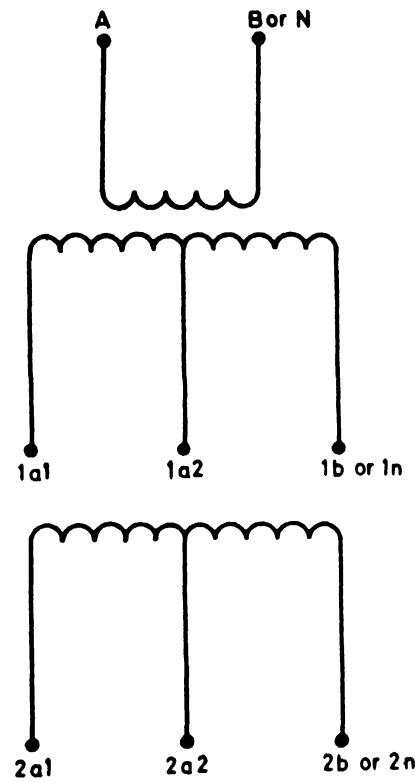

FIG. 8 SINGLE-PHASE TRANSFORMER WITH TWO MULTI-TAP SECONDARIES

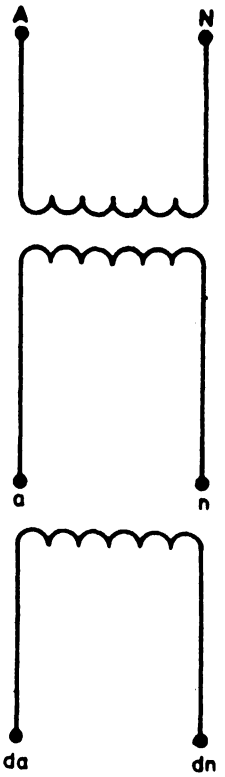

FIG. 9 SINGLE-PHASE TRANSFORMER WITH ONE RESIDUAL VOLTAGE WINDING

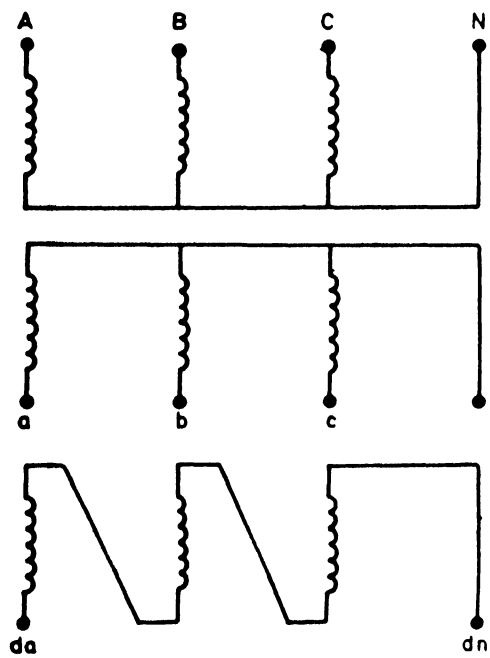

FIG. 10 THREE-PHASE TRANSFORMER WITH ONE RESIDUAL VOLTAGE WINDING

ANNEX D

(Clause 9.5)

METHODS OF TEMPERATURE MEASUREMENT

D-1 SELF RESISTANCE METHOD

D-1.1 In the self-resistance method, the temperature-rise of winding is determined by the increase in the resistance of the conductor itself.

D-1.1.1 The temperature of the winding and the oil or other medium surrounding the winding measured before beginning the test should not differ. The initial resistance and the initial temperature of the winding should be measured under steady temperature conditions, at the same time.

D-1.1.2 Since the resistance of copper over a range of temperature varies in direct proportion to the temperature as measured from minus 234.5°C, the ratio of the hot temperature (T_2) to the cold temperature (T_1) may be calculated from the ratio of the hot resistance (R_2) to the cold resistance (R_1) as follows:

$$\frac{R_2}{R_1} = \frac{T_2 + 234.5}{T_1 + 234.5}$$

$$\text{or } T_2 = \frac{R_2}{R_1}(T_1 + 234.5) - 234.5$$

D-1.1.3 The temperature-rise is the difference between the calculated temperature T_2 and that of the surrounding air at the conclusion of the test.

D-1.2 The method of testing by increase in resistance is applicable at the ambient temperature of the test room to all windings having a resistance of not less than 0.01 ohm. For windings having a resistance of less than 0.01 ohm, the surface temperature should be taken by thermometer or thermocouple.

D-2 THERMOMETER METHOD

D-2.1 Three types of thermometers may be employed, namely bulb thermometers containing mercury or alcohol and resistance thermometers.

D-2.2 When bulb thermometers are used in places where there is any varying or moving magnetic field, those containing alcohol should be used in preference to those containing mercury in which eddy currents may produce sufficient heat to yield misleading results.

D-2.3 When a thermometer is used to measure the temperature of a surface such as that of a winding, the bulb shall be surrounded by a single wrapping of tin foil having a thickness of not less than 0.025 mm. The tin foil shall form a complete covering for the bulb, which shall then be secured in contact with the surface under test. The exposed part of the wrapped bulb shall be completely covered with a pad of heat-insulating material, without unduly shielding the test surface from normal cooling.

D-3 THERMOCOUPLE METHOD

D-3.1 The two conductors between which the thermoelectric effect is produced shall be welded at both the hot and cold junction (*see* IS 2053 : 1974).

D-3.2 When applied to the surface the temperature of which is to be measured, the hot junction shall be covered with insulation and wrapped with tin foil as described for bulb thermometers. The thermocouple circuits shall be earthed to minimize the possibility of capacitance currents.

D-3.3 The protecting pad of heat insulating material specified in D-3.2 shall be employed whether the junction is insulated or not.

D-3.4 The cold junction shall be maintained at a steady temperature. When an oil bath is used, the oil should preferably be contained in a vacuum flask or be thermostatically controlled, and the oil temperature shall be measured by means of a thermometer.

D-4 MEASUREMENT OF AMBIENT TEMPERATURE

D-4.1 The temperature of the surrounding air shall be measured by means of at least two thermometers, so placed as to take account of the maximum and minimum temperatures, and the mean reading shall be adopted.

ANNEX E
(*Clause* 10.1)

INFORMATION TO BE GIVEN WITH ENQUIRY AND ORDER

At the time of enquiry and order, the following information shall be given:

1. Type of transformer
   (e.g. single/three phase, indoor/outdoor, resin cast/oil immersed, etc).
2. Highest system voltage, type of supply and earthing conditions
   (e.g. 145 kV, 3-phase, effectively earthed).
3. Rated Insulation level.
   (e.g. 230/550 kV)
4. Frequency, if other than 50 Hz.
5. Rated Transformation ratio
   (e.g. 6.6/0.11 kV or $132/\sqrt{3} : 0.11/\sqrt{3}$ kV)
6. Rated output and corresponding accuracy class for measuring or protective voltage transformers.
   (e.g. 100VA/0.5 for a measuring voltage transformer or 100VA/3P for a protective voltage transformer)
7. Rated voltage factor and duration.
   (e.g. 1.5/30s)

NOTE – The rated voltage factor is dependant on the earthing conditions (*see* Table 1) and it is necessary to specify this only if the earthing conditions have not been specified.

8. Residual voltage for residual voltage windings.
9. Service conditions including, for example, whether the voltage transformers are for use indoors or outdoors, whether for use at unusually low temperature, altitudes (if over 1 000 metres), humidity, and any special conditions likely to arise, such as exposure to steam or vapour, fumes, explosive gases, vibrations, excessive dust, etc.
10. Whether the installation is electrically exposed and the atmospheric pollution conditions.
11. Special features such as limiting dimensions.

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